

CLAIMS

What is claimed is:

- 1 1. In a computer program, a method for maintaining dependencies among a set of objects each
2 having a value, the set of objects including an object A and an object B, the method for maintaining
3 dependencies comprising:
4 when the value of object A is a function of the value of object B and the value of object B
5 changes, marking object A as dirty and not recomputing the value of object A until object A is
6 queried for a value;
7 when the value of object B changes, invalidating the dependents of object B and all of their
8 further dependents, including severing dependencies among the dependents of object B and all of
9 their further dependents; and
10 causing each invalidated observer-only object to recompute its value by querying the values
11 of the objects from which the observer-only object depends.
- 1 2. The method of claim 1, further comprising:
2 providing object B in the construction of object A, wherein the value of object A is a
3 function of the value of the object B that was provided in the construction of object A.
- 1 3. The method of claim 1, further comprising:
2 providing in object B a handleRequest method that adds a requester owned by object A to a
3 dependents list for object B, the dependents list identifying all objects whose value is a function of
4 the value of object B.
- 1 4. The method of claim 3, wherein the dependents lists for all objects in the set collectively define a
2 directed, acyclic dependency graph.

1 5. The method of claim 1, further comprising:

2 when an object is marked as dirty, breaking any dependency relationships the marked object
3 may have had; and

4 when the value of an object is recomputed, identifying the objects on which the recomputed
5 value is actually dependent and identifying the recomputed object as dependent only on the
6 identified objects.

1 6. The method of claim 1, wherein the set of objects includes settable objects and dependent objects,
2 and each dependent object maintains a flag whose setting marks the dependent object as valid or
3 invalid (i.e., dirty).

1 7. In a computer program, a method for maintaining dependencies among a set of objects each
2 having a value, the method for maintaining dependencies comprising:
3 identifying the objects upon which a given object depends as those objects into which the
4 given object passed itself as a requester during execution of a compute method of the given object;
5 and

6 marking the given object as dirty whenever the value of any one of the identified objects
7 changes and not recomputing the value of the given object until the given object is queried for a
8 value.

1 8. The method of claim 7, further comprising:

2 identifying as dependents of a root object all objects that passed themselves as requester
3 objects to the root object or to a dependent of the root object during execution of the requester
4 objects' respective compute methods, whereby the set of dependents of the root object is a set that
5 changes based on the computation of dependents and not the root object itself.

1 9. The method of claim 7, wherein the set of objects includes settable objects and dependent objects,
2 and each dependent object maintains a flag whose setting marks the dependent object as valid or
3 invalid (i.e., dirty).

1 10. A method for making an operation in a computer program application consistent, the operation
2 comprising one or more queries for values of one or more objects having values, each query
3 operating to read the value of an object, the method comprising:

4 using a requester object to make each of the operation's queries;
5 establishing a requester-object relationship with each object whose value is available to be
6 queried by the operation; and

7 if the value of any of the one or more objects is unavailable to be read by the operation, then
8 interrupting the operation, terminating all of the operation's requester-object relationships, and then
9 retrying the operation.

11. A method for changing objects having values defining state of a computer program application,
comprising:

3 receiving a change to a value of a changed object, the changed object being a settable object
4 in the application;

5 registering the change with a transaction;
6 dirtying all objects dependent (directly or indirectly) on the changed object; and

7 whenever a leaf object is encountered as a dependent object, enqueueing the leaf object for
8 synchronization after the transaction is committed.

12. The method of claim 11, further comprising:

2 severing dependencies from the changed object and all of its direct and indirect dependent
3 objects.

13. The method of claim 11, wherein leaf object synchronization comprises:

2 recomputing a value for each objects marked as dirty, identifying the objects on which the
3 recomputed value is actually dependent, and identifying the recomputed object as dependent only on
4 the identified objects.

1 14. The method of claim 13, further comprising:

2 using a requester object to make the transaction consistent, the requester object operating to
3 request an object's value so that the requested value cannot change until the requester terminates, at
4 which time all objects whose values were requested by the requester object are released.

1 15. A method for changing objects defining state of a computer program application, comprising:

2 creating a transaction registering with the transaction one or more changes to settable
3 objects, each change being made to a corresponding changing object;

4 for each change registered, traversing a dependency graph from the changing object and (i)
5 for each dependent object on the dependency graph, marking the dependent object as dirty and
6 detaching the dependent object from the dependency graph, and (ii) accumulating each leaf object
7 encountered in traversing the dependency graph in a strobe queue; and

8 traversing the strobe queue after all changes to settable objects have been registered and
9 synchronizing each leaf object by recomputing values for objects marked as dirty and rejoining
10 recomputed objects with the dependency graph, whereby leaf objects are rejoined with the
11 dependency graph.

1 16. The method of claim 15, wherein:

2 the dependency graph represents application state;

3 the roots of the dependency graph are the settable objects of the application state; and

4 the intermediate nodes of the dependency graph are dependent objects whose values are the
5 results of intermediate computations.

1 17. The method of claim 15, wherein:

2 the leaf objects of the dependency graph are coupled to a user interface.

1 18. The method of claim 17, wherein:

2 the leaf objects are coupled directly to the user interface.

1 19. In a computer program, a method for managing dependency among a set of objects, each object
2 of the set having a value, the set including dependent objects, each dependent object having a value
3 that is a function of the values of one or more of the other objects in the set, the method comprising:
4 calculating the dependency among objects in the set dynamically at the time objects calculate
5 their values.

1 20. The method of claim 19, wherein each observed object in the set has one or more accessor
2 methods that each take an requester argument and returns a current value of the observed object, the
3 requester argument identifying the object requesting the value of the observed object.

1 21. The method of claim 19, wherein each settable object in the set has an value-setting method that
2 takes two arguments, namely a transaction argument identifying a transaction with which the change
3 to the settable object's value is registered and a new value for the settable object.

1 22. The method of claim 19, wherein:
2 each object in the set descends from a VValue class;
3 each computation operation is represented by a Requester object that is owned by a
4 dependent VValue object, and the Requester object enters the dependent set of one or more VValue
5 objects from which the dependent VValue object depends; and
6 the dependent object uses the Requester object to obtain the object values the dependent
7 object needs to calculate its own value.

1 23. The method of claim 22, wherein a Transaction class descends from the Requester class, the
2 method further comprising:
3 accumulating changes to one or more settable VValue objects in a Transaction object; and
4 executing the Transaction object.

1 24. A method for providing a dependency management system for managing application state in a
2 consistent manner, comprising:

3 providing a VValue class for objects having values representing application state; and
4 providing in VValue objects a handleRequest method that, when executed, causes an object
5 A to be identified in a dependents list for an object B, the dependents list identifying all objects
6 whose value is a function of the value of VValue object B.

1 25. The method of claim 24, wherein:

2 the method further comprises providing a Requester class, a Requester object being operable
3 to guarantee consistency in values queried from VValue objects by locking requested VValue values
4 until an operation invoking the Requester object terminates; and

5 the handleRequest method takes as an argument a Requester A owned by the object A and
6 causes the Requester A to be added to the dependents list for the object B, the dependents list
7 containing Requesters owned by all objects whose value is a function of the value of the object B.

1 26. The method of claim 24, wherein the dependency management system is transaction-based.

1 27. The method of claim 24, wherein the dependency management system is threadsafe.

1 28. A system for maintaining dependencies among a set of objects in a computer program, each
2 object having a value, the set of objects including an object A and an object B, the system
3 comprising:

4 means for recomputing the value of object A, wherein when the value of object A is a
5 function of the value of object B and the value of object B changes, marking object A as dirty and
6 not recomputing the value of object A until object A is queried for a value;

7 means for recomputing the value of object B, wherein when the value of object B changes,
8 invalidating the dependents of object B and all of their further dependents, including severing
9 dependencies among the dependents of object B and all of their further dependents; and

10 means for causing each invalidated observer-only object to recompute its value by querying
11 the values of the objects from which the observer-only object depends.

1 29. A system for maintaining dependencies among a set of objects in a computer program, each
2 object having a value, the system comprising:

3 means for identifying the objects upon which a given object depends as those objects into
4 which the given object passed itself as a requester during execution of a compute method of the
5 given object; and

6 means for marking the given object as dirty whenever the value of any one of the identified
7 objects changes and not recomputing the value of the given object until the given object is queried
8 for a value.

1 30. A system for making an operation in a computer program application consistent, the operation
2 comprising one or more queries for values of one or more objects having values, each query
3 operating to read the value of an object, the system comprising:

4 means for using a requester object to make each of the operation's queries; and

5 means for establishing a requester-object relationship with each object whose value is
6 available to be queried by the operation; wherein

7 if the value of any of the one or more objects is unavailable to be read by the operation, then
8 interrupting the operation, terminating all of the operation's requester-object relationships, and then
9 retrying the operation.

1 31. A system for changing objects having values defining state of a computer program application,
2 comprising:

3 means for receiving a change to a value of a changed object, the changed object being a
4 settable object in the application;

5 means for registering the change with a transaction; and

6 means for dirtying all objects dependent (directly or indirectly) on the changed object;

7 wherein

8 whenever a leaf object is encountered as a dependent object, the leaf object is enqueued for
9 synchronization after the transaction is committed.

32. A system for changing objects defining state of a computer program application, comprising:
means for creating a transaction registering with the transaction one or more changes to
settable objects, each change being made to a corresponding changing object;
means for traversing a dependency graph, for each change registered, from the changing
object and (i) for each dependent object on the dependency graph, marking the dependent object as
dirty and detaching the dependent object from the dependency graph, and (ii) accumulating each leaf
object encountered in traversing the dependency graph in a strobe queue; and
means for traversing the strobe queue after all changes to settable objects have been
registered and synchronizing each leaf object by recomputing values for objects marked as dirty and
rejoining recomputed objects with the dependency graph, whereby leaf objects are rejoined with the
dependency graph.

33. A system for managing dependency among a set of objects in a computer program, each object
of the set having a value, the set including dependent objects, each dependent object having a value
that is a function of the values of one or more of the other objects in the set, the system comprising:
means for determining a time at which objects calculate their values; and
means for calculating the dependency among objects in the set dynamically at the time
objects calculate their values.

34. A system for providing a dependency management system for managing application state in a
consistent manner, comprising:
means for providing a VValue class for objects having values representing application state;
and
means for providing in VValue objects a handleRequest method that, when executed, causes
an object A to be identified in a dependents list for an object B, the dependents list identifying all
objects whose value is a function of the value of VValue object B.

35. A computer program product, tangibly stored on a computer-readable medium, for maintaining
dependencies among a set of objects each having a value, the set of objects including an object A
and an object B, the product comprising instructions operable to cause a computer to:

4 recompute the value of object A, wherein when the value of object A is a function of the
5 value of object B and the value of object B changes, object A is marked as dirty and the value of
6 object A is not recomputed until object A is queried for a value;

7 recompute the value of object B, wherein when the value of object B changes, the dependents
8 of object B and all of their further dependents are invalidated, and the dependencies among the
9 dependents of object B and all of their further dependents are severed; and

10 cause each invalidated observer-only object to recompute its value by querying the values of
11 the objects from which the observer-only object depends.

1 36. A computer program product, tangibly stored on a computer-readable medium, for maintaining
2 dependencies among a set of objects in a computer program, each object having a value, the product
3 comprising instructions operable to cause a computer to:

4 identify the objects upon which a given object depends as those objects into which the given
5 object passed itself as a requester during execution of a compute method of the given object; and

6 mark the given object as dirty whenever the value of any one of the identified objects
7 changes and not recompute the value of the given object until the given object is queried for a value.

1 37. A computer program product, tangibly stored on a computer-readable medium, for making an
2 operation in a computer program application consistent, the operation comprising one or more
3 queries for values of one or more objects having values, each query operating to read the value of an
4 object, the product comprising instructions operable to cause a computer to:

5 use a requester object to make each of the operation's queries;

6 establish a requester-object relationship with each object whose value is available to be
7 queried by the operation; and

8 interrupt the operation if the value of any of the one or more objects is unavailable to be read
9 by the operation, terminating all of the operation's requester-object relationships, and then retry the
10 operation.

38. A computer program product, tangibly stored on a computer-readable medium, for changing objects having values defining state of a computer program application, the product comprising instructions operable to cause a computer to:

- receive a change to a value of a changed object, the changed object being a settable object in the application;
- register the change with a transaction;
- dirty all objects dependent (directly or indirectly) on the changed object; and
- whenever a leaf object is encountered as a dependent object, enqueue the leaf object for synchronization after the transaction is committed.

39. A computer program product, tangibly stored on a computer-readable medium, for changing objects defining state of a computer program application, the product comprising instructions operable to cause a computer to:

- create a transaction registering with the transaction one or more changes to settable objects, each change being made to a corresponding changing object;
- traverse a dependency graph, for each change registered, from the changing object and (i) for each dependent object on the dependency graph, marking the dependent object as dirty and detaching the dependent object from the dependency graph, and (ii) accumulating each leaf object encountered in traversing the dependency graph in a strobe queue; and
- traverse the strobe queue after all changes to settable objects have been registered and synchronizing each leaf object by recomputing values for objects marked as dirty and rejoining recomputed objects with the dependency graph, whereby leaf objects are rejoined with the dependency graph.

40. A computer program product, tangibly stored on a computer-readable medium, for managing dependency among a set of objects in a computer program, each object of the set having a value, the set including dependent objects, each dependent object having a value that is a function of the values of one or more of the other objects in the set, the product comprising instructions operable to cause a computer to:

- calculate the dependency among objects in the set dynamically at the time objects calculate their values.

1 41. A computer program product, tangibly stored on a computer-readable medium, for providing a
2 dependency management system for managing application state in a consistent manner, the product
3 comprising instructions operable to cause a computer to:

4 provide a VValue class for objects having values representing application state; and

5 provide in VValue objects a handleRequest method that, when executed, causes an object A
6 to be identified in a dependents list for an object B, the dependents list identifying all objects whose
7 value is a function of the value of VValue object B.